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Special Operations Mission Planning and Analysis Support System

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ABSTRACT

Current mission preparation and analysis methods place an undue burden of effort on conventional and special operations forces to effectively synchronize and execute their increasingly complex operational responsibilities in a rapidly changing global environment. This project developed a tool for the United States Special Operations Command (USSOCOM) in support of their Mission Planning, Analysis, Rehearsal, and Execution (MPARE) initiative to allow special operations forces commanders and staffs to conduct mission planning and analysis in a distributed environment, and rapidly produce dynamic synchronization matrices and scheduling products. Operations research methods provide the foundation for the analysis. The system developed in this project is called the Special Operations Mission Planning and Analysis Support System (SOMPASS). SOMPASS is simple to learn and operate, provides dynamic changes with little effort, and is universal in application. This system has the capability to execute on any hardware platform, operate across any network connection, and expand easily to support additional users and requirements. This project provides not only a demonstration of capabilities through a special operations oriented illustrative scenario, but also a working product that can be adapted for use in mission planning and analysis by all units under USSOCOM.

INTRODUCTION AND MOTIVATION

Since the end of the Cold War, the United States faces an increasingly complex and diverse set of challenges due to our role as the world's only remaining superpower with worldwide presence and global power projection responsibilities. In this modern era, technological advances in communications and the increased pace of world events can produce crises that rapidly expand in unpredictable ways, thereby reducing the time available to prepare and employ forces to defuse these critical situations. Thus, some of the same technological advances that improve our military capabilities strain our forces by increasing the difficulty and complexity of military operations and confound our ability to react to and defuse these crises. (Joint Pub 1, 1995) In a military that operates by

force-projection, such as we do today, synchronization of operations is paramount (FM 100-5, 1993).

Successful planning can help offset these potential operational problems, though time limitations will always have an overarching impact. Tactical and operational planning must be a continuous process, frequently concurrent with ongoing operations, which further complicates its completion. Successful planning requires an understanding and appreciation of this simultaneous nature, and an ability to anticipate likely future events to counter shortfalls or exploit successes. Detailed synchronization during the planning and execution of the mission will promote successful achievement of the mission objectives. Synchronization requires a clear commander's intent to convey to the staff the idea for the sequence and flow of the operation that must then be developed in the plan with coordination of movement, fires, and supporting activities. This is an extremely complex process wherein coordination, collaboration, and rehearsal are keys to success in providing "...the ability to focus resources and activities in time and space to produce maximum relative combat power at the decisive point." (FM 100-5, 1993: p. Glossary-8)

A tool that assists the commander or staff in this synchronization process will therefore greatly enhance their capabilities and the ability of their units to conduct successful operations and achieve victory.

As the world environment continues to change and present more complex challenges, our forces must also adapt to this changing environment to preserve our ability to defend against current and emerging threats to our national security. This includes not only our weapons, doctrine, and training, but also the tools we use to assist in the accomplishment of our missions. *Joint Vision 2010* (1996) provides a template for the continuing development and advancement of our nation's warfighting capability into the future by leveraging advances in information-age technology through the development of four operational concepts: dominant maneuver, precision engagement, full dimensional protection, and focused logistics. Technological superiority has been crucial in our prior successes in combat, and will continue to be so in the foreseeable future. Therefore, continuing advances in information and systems integration technologies must be aggressively developed to provide decision-makers with accurate and timely information to gain "dominant battlespace awareness." (*Joint Vision 2010*, 1996)

The United States Special Operations Command (USSOCOM) also has a vision for the future that expands on the concepts outlined in *Joint Vision 2010* and applies them to the nature of Special Operations and the role of Special Operations Forces (SOF). *SOF Vision 2020* (1996: p1) "...provides a long-range strategy for SOF missions, force structure, equipment, and capabilities into and beyond 2020." It outlines defining characteristics that focus on quality, well-trained personnel with a superior technological edge who provide military capabilities not available with conventional forces (*SOF Vision 2020*, 1996). Additionally, *Special Operations Forces: The Way Ahead* (1998, p7) expands on the relevance of SOF and their unique abilities, as well as their need to "...examine every advantage our technological genius can supply...selectively exploit those few required for success...[and] leverage those critical technologies that give us a decided advantage."

A common thread throughout all of these documents is the importance of information technologies and the critical role they play in the advancement and

success of our forces in future conflicts. The sooner we begin the development of these needed systems, the sooner we will be able to leverage technology to our advantage. Although we currently have many advanced systems in our inventory, technology has far outpaced development and acquisition, and many commercially available systems are neither well suited nor easily adaptable to military use. As the United States is not the only bastion of technological advancement, we must make a concerted effort to foster developments to ensure we do not fall behind the advances of any current or potential adversaries.

Paramount among the choices for development of future technological systems is a solution to address shortcomings in mission planning and analysis. Our increasing reliance on superiority in command, control, communications, computers, and intelligence (C4I) highlights the need for more than current systems can provide and interim solutions will offer. All of the new operational concepts put forward in *Joint Vision 2010* will rely significantly on advanced C4I systems and capabilities. But in particular, "Dominant maneuver will require forces that are adept at conducting sustained and synchronized operations from dispersed locations." (*Joint Vision 2010*, 1996: p20) The ability to meet this mandate will depend on systems that offer extremely capable tools with superior flexibility and interoperability.

Despite this recognized need for a superior technology system to assist commanders, staffs, and their forces in all aspects of operations from mission planning to execution, no satisfactory system has yet been developed or fielded. Quite the contrary, most units, including conventional and special operations forces, use many of the same techniques that have been in use since World War II and throughout the Cold War era.

Readily available commercial tools do not provide the needed capabilities, flexibility, or adaptability required in supporting complex military operations, nor address the specific requirements outlined in either *Joint Vision 2010* or the USSOCOM documents. Additionally, currently fielded military planning systems that are in use today are also significantly lacking in flexibility, usually offer only limited static solutions, and adhere to monolithic standards (Bradley and Buss, 1998). Any possible solution must therefore overcome current shortcomings and address the specific needs mentioned.

In an extensive effort to address critical Special Operations mission challenges, USSOCOM began the Mission Planning, Analysis, Rehearsal, and Execution (MPARE) initiative in 1997. The goal of MPARE is to provide SOF commanders, staffs, and operators a totally integrated "system of systems" with which they can efficiently plan, analyze, rehearse, and execute the full spectrum of Special Operations missions. This system will also provide communications services and collaborative capabilities between elements both vertically and horizontally to facilitate information flow and synchronization. It is intended to be ubiquitous, to support all operations in training and combat environments, as well as handle routine administrative functions. The key components of MPARE will enable SOF units to collaboratively plan missions from geographically separate locations, analyze different courses of action (COAs), preview and rehearse options, and monitor execution in real-time. (USSOCOM, 1999)

Although still in the early developmental stage, MPARE is laying the groundwork for an in-depth understanding of the true requirements for the C4I systems of the future which will not only greatly benefit USSOCOM, but also the DoD and

the Services who have been trailing behind with their own systems.

Many current military planning and support systems offer tools that employ operations research techniques, but the rapid increase in complexity of military operations since the end of the Cold War, along with advances in technology, have rendered these systems either obsolete or insufficient. More powerful and flexible tools for future systems and capabilities outlined in *Joint Vision 2010* and USSOCOM initiatives will continue to depend on operations research techniques, not only to facilitate their development, but also for incorporation within these systems.

Commanders and staffs can benefit from advances made using operations research techniques in all aspects of military operations, including mission planning, decision support, and logistics management. These benefits underscore the relevance of continued study in the area of operations research applications to military problems to stay ahead of our current and potential adversaries in a rapidly changing world.

PROBLEM

USSOCOM has outlined a need for a capable system to support the conduct of Special Operations missions. One of the critical components to the success of such a system is the ability to synchronize these missions. As mentioned previously, current methods for addressing this need fall far short of the requirement.

Once given a mission and set of goals and objectives, commanders and staffs have to conduct extensive preliminary work during mission planning and analysis to determine what must be done, who must do it, what is needed, and how it should be accomplished. This itself is a significant challenge, usually compounded in difficulty by the common constraint of extremely limited preparation time before mission execution. Components of this process involve breaking down a mission into its specified, implied, and essential tasks; identifying critical decision points, developing a concept of the operation and COAs; wargaming the COAs; and producing the operations order (OPORD). To help develop the best possible plans for success, commanders and staffs need to conduct wargaming and analysis to determine if their plans are feasible and accomplish all objectives as desired, and also to choose the best among the alternatives developed. Then, they must develop a synchronization matrix that ties all units and required resources to support the operation to an interdependent time schedule based on expected mission status and probable enemy COAs. This process is very time-consuming and prone to errors. Additionally, since one of the critical end products, the synchronization matrix, is usually constructed by hand on a large sheet of paper or an overlay, any change to an event, time, or status requires complete reconstruction. Due to the very complex nature of military operations, and in particular, Special Operations, synchronization is extremely difficult because numerous decisions, personnel, equipment, supplies, and actions must come together at critical times and locations throughout the battlespace to produce the desired effect of success in the assigned mission objectives. Clearly, the current process does not support rapid or flexible planning, nor facilitate any sensitivity analysis.

Many commercial software tools currently exist that perform functions similar to synchronization planning; however, none of them are well suited to military operations. These commercially available tools perform functions such as project management or resource and event tracking, but none provide the required capabilities,

flexibility, or adaptability required in supporting complex military operations. In addition, most only operate on single machines or small local area networks (LANs), and all gear their functionality toward commercial applications. Consequently, military commanders and staffs have shunned these commercially available tools and relied on their time-tested, manual methods of planning, analysis, and synchronization.

Special Operations, as well as conventional military operations, have unique requirements that demand special capabilities that are neither provided by commercially available systems, nor available on the current generation of limited functionality military planning systems. A tool that would support commanders and staffs in accomplishing the complex task of synchronization planning and generate useful products in a rapid, flexible, and distributed environment would become a key component in the MPARE initiative.

PROPOSAL

The purpose of this project is to develop a mission planning and analysis tool to support Special Operations Forces commanders and staffs by identifying and presenting critical mission events, relationships, and dependencies in a simple and understandable format. Many of the technologies that support the needs of the mentioned desired future systems are available now, but have not been combined into a working system. Most efforts in development are attempting to produce a complete system with full functionality to satisfy all needs when fielded. This approach requires intense and coordinated effort, along with substantial time and funding. This project does not attempt to put forward a complete solution; rather it presents a working technical demonstration that can be incorporated into a larger system while still demonstrating specific desired functionality.

This tool will assist special operations commanders and staffs to conduct mission planning and analysis by operating in a collaborative and dynamic environment that allows simple task and event entry and analysis. It will rapidly produce synchronization matrices and scheduling products that are easily updated as changes occur during any phase of the operation, and also allow mission sensitivity analysis through visual depiction of impacts based on task, event requirement, or resource availability changes. In addition to its functionality, this tool will also provide USSOCOM with one possible direction for further development and possible incorporation into the MPARE system, as well as demonstrate the power and importance of operations research tools to military decision-makers.

The Special Operations Mission Planning and Analysis System (SOMPASS) has been designed to address the needs of USSOCOM and Special Operations Forces. This and similar systems that embrace the goals of MPARE will be useful to the DoD and all the Services due to their inherent "jointness." This is especially important for USSOCOM because it must deal with all of these disparate players on a continuous basis. The system is required to:

- Execute on any hardware platform used by SOF
- Provide on-the-fly incorporation of new programs and capabilities
- Operate across any network connection to all participants at all levels
- Execute quickly and efficiently on devices with limited memory and storage
- Expand easily to support additional users and processing requirements as needed

While this system alone cannot answer all the needs of MPARE, it is designed to be an integral component in a larger system that will provide military decision-makers the tools to achieve their goals.

Critical path analysis of networks for project management can be readily applied to military operational planning, just as it has to many large-scale complex engineering scheduling problems. Critical path analysis highlights the complexities and relationships of activities or tasks that make up a project or mission, and allows for detailed analysis, simple modification, and flexible evaluation to support decision making. (Morris, 1967) SOMPASS takes advantage of this power to solve military operational planning problems by treating an operation as a graph representation of a network.

SOMPASS is designed to meet the requirements outlined above and provide not only a demonstration of capabilities to foster further development, but also a working product that can be used to solve current problems. Several requirements are achieved by implementing the system in the Java programming language, while others are achieved through other capabilities developed by a group of faculty and students at the Naval Postgraduate School.

Platform independence is achieved by using the Java programming language. A significant capability of Java and an advantage over many other programming languages is its inherent platform independence. Programs can be written and compiled once on one computer platform and then be executed without modification on a number of other computers and operating systems. USSOCOM and SOF units use different computer systems with different processors, capabilities, and operating systems. In fact, these units have the most diverse range of systems within the DoD due to their unique missions and requirements. As such, they have the greatest challenge to interoperate and intercommunicate, not only among themselves, but also with external agencies, forces, and nations. Java's ability to operate on any hardware system without modification, from the largest mainframe to the smallest handheld device, offers incredible power and flexibility.

Mission planning does not end with the onset of the execution phase. Continuous monitoring, or "battle tracking," during all phases of an operation are critical to mission success, thus a capability to react immediately to changing or unforeseen events is critical to any military decision support system. The system builds on Java's dynamic loading and execution functionality to provide enhanced capabilities that offer real-time updates to software and capability enhancements, even after the system has been started. For example, a new algorithm or capability needed at a remote location can be written and compiled elsewhere, sent to the unit in need across any available network connection, and then incorporated into ongoing planning or analysis seamlessly to solve a problem without any need to restart the system. (Bradley et al, 1998)

Additionally, the system put forward in this research can receive updated information about units or items of interest and display those changes real-time, without any action required by the user. This is extremely relevant when dealing with mission areas such as intelligence, surveillance, and reconnaissance, as well as traditional battle tracking.

Special Operations Forces usually operate in diverse and disparate environments; the ability to have access to and share critical mission information from remote locations offers a significant advantage over current isolated systems. Planning of these complex operations can

involve numerous forces, agencies, and activities whose actions and efforts must be coordinated to achieve their objectives, yet are usually unable to consolidate at a single location, thereby necessitating the system to operate in a distributed manner. (Bradley and Buss, 1998; Bilyeu, 1998) The network-focused nature of Java allows for simple sharing and distribution of data and programs required to operate this system. This capability allows the system to inter-operate with different components and elements of data that may be physically in different locations. Some resources may be on the local system, while others might be accessed across a network connection from a system that is on a different continent.

The system allows dynamic adjustment and updates to facilitate wargaming and sensitivity analysis of COAs, as well as highlight potential bottlenecks during the rehearsal and execution phases if linked to real-time operational data or notional scenario modifications or events. The integrated analysis and update capabilities provide powerful functionality that cannot be achieved with current manual methods of synchronization and traditional wargaming exercises. The automated analysis also facilitates rapid identification of the critical elements or events of an operation that may warrant special attention by commanders or staffs due to their influence or leverage on the overall synchronization of the operation, and possibly its success or failure.

After successfully solving for the project critical path, the principal features of this system can be exercised — they produce the mission synchronization matrix and unit execution checklists.

The synchronization matrix produced by this system presents a time sequenced, unit-hierarchical view of the mission similar to one that would be produced manually during the mission planning sequence. The synchronization matrix produced by this system is more valuable than those constructed manually because of its interactive and dynamic properties. Updates made to the underlying properties of the events or tasks in a mission model will produce corresponding changes in the resultant mission critical path and its synchronization matrix and execution checklists. The execution checklists produced by the system are created for each unit or differentiated element, show a chronological view of the tasks and events for that particular unit, and can be easily distributed to the units concerned or command and control elements. Their automatic generation and dynamic updating tremendously reduces the workload of staffs and subordinate elements to obtain useful mission products and operational aids.

MODEL

The system put forward in this project uses an operations research approach with the theory and foundations of graph theory, project management techniques, and critical path analysis to implement a usable product that can assist commanders and staffs in planning, analysis, and decision-making by providing a set of tools that allow the construction of models of military operations as networks and applying solution algorithms and display components to simplify the complex task of mission synchronization.

There are two extensively used critical path analysis project management techniques that can be applied to military operational planning: the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). There are many similarities between the two methods, and both are principally concerned with planning, scheduling, and control, which are key components to the success of all military operations.

Both techniques help answer detailed questions about dependencies between tasks and events in a project or mission, and can easily support comparative analysis when faced with questions about scheduling or resource changes or disruptions. They both support decision-making without requiring complex calculations or analysis by the user. (Wiest and Levy, 1969; Kerzner, 1989) Each technique has both advantages and disadvantages depending on the type of mission or problem of interest.

CPM assumes the time required to complete individual tasks in a project is known with certainty. This is an assumption that greatly simplifies the underlying calculations while providing consistent results, but may not be as applicable to a project where there are large or unknown variances in the execution or completion times of component tasks that may severely affect completion times. (Wiest and Levy, 1969)

Although similar in purpose, PERT differs primarily from CPM in that it assumes that task completion times are uncertain and independent of one another. This technique requires additional input from the user that may not be intuitive or readily available. Although military operations involve great uncertainty, assumptions about the distributions or variance of random quantities, especially those related to the actions or responses of enemy forces, is very difficult. Consequently, PERT may be more harmful than helpful when doing military planning if improper assumptions are used in mission formulation, rather than simply using a deterministic approach such as CPM.

Consequently, the system put forward in this research employs CPM for simplicity of use, timeliness and consistency of results, and to reduce the reliance on assumptions by the user that require more information about component tasks than may be available or verifiable.

Solving for the critical path in a network is essentially looking for the longest path in both directions between the start and finish points of a project to determine where there is no flexibility of movement, or slack, in either direction.

The longest path can be solved as a linear programming problem as shown in Figure 1 (Ahuja et al, 1993) using standard linear optimization techniques, or more efficiently using the network algorithms described later.

Maximize: $\sum_{\{j:(i,j)\in A\}} c_{ij} \cdot x_{ij}$

Subject to: $\sum_{\{j:(j,i)\in A\}} x_{ji} - \sum_{\{j:(i,j)\in A\}} x_{ij} = \begin{cases} -1 & i = s \\ 0 & \forall i \in N - \{s,t\} \\ 1 & i = t \end{cases}$

$x_{ij} \geq 0 \quad \forall (i,j) \in A$

Define:

$G(A,N)$	graph G composed of the set of arcs A and the set o
x_{ij}	binary use variable for arc (i,j)
c_{ij}	duration of arc (i,j)
s	the start node
t	the finish node

Figure 1. Longest Path Linear Program

The two key network algorithms that are needed to solve for the critical path in a project or mission are a topological sort algorithm and a longest path algorithm. The functions of both algorithms can actually be combined into one dual-purpose algorithm making an extremely efficient critical path solver that is used in this project.

The topological sort algorithm is necessary in critical path analysis to verify that the network is ordered properly from mission start to finish and that there are no cycles. A cycle, where an activity would loop back to an already completed event, would only occur due to a data entry or logic error. A cycle causes an infinite duration loop preventing the mission from ever completing. The topological sort is a very efficient algorithm that can be solved in linear time proportional to the number of

arcs in the network with worst case complexity of O(|A|) (Ahuja et al, 1993). A representation of a simple topological sort algorithm is shown in Figure 2 (Ahuja et al, 1993; Wood, 1998).

```
algorithm TopologicalSort;
data G(A,N), the graph G composed of the set of arcs A and the set of nodes N
begin
    for ∀i ∈ N do indegree(i) ← 0;
    for ∀(i,j) ∈ A do indegree(j) ← indegree(j) + 1;
    LIST ← Ø;
    next ← 0;
    for ∀i ∈ N do
        if indegree(i) = 0 then LIST ← LIST ∪ {i};
    while LIST ≠ Ø do
    begin
        select a node i ∈ LIST;
        LIST ← LIST − {i};
        next ← next + 1;
        order(i) ← next;
        for ∀(i,j) ∈ A(i) do
        begin
            indegree(j) ← indegree(j) − 1;
            if indegree(j) = 0 then LIST ← LIST ∪ {j};
        end;
    end;
    if next < n then G(A,N) contains a directed cycle
    else G(A,N) is acyclic and LIST contains a topological ordering of nodes
end;
```

Figure 2. Topological Sort Algorithm

The longest path algorithm involves a very simple operation where each node in a network is examined in topological order for the greatest distance between the node and all of the nodes that occur before it, its predecessors, using a series of pair-wise comparisons leading back to the start node. In each pair-wise comparison, the larger of the current longest path associated with the node or the sum of a predecessor node's longest path and the length of the arc connecting them will become the new longest path for a particular node. As with the topological sort algorithm, the longest path in a network can be solved in linear time proportional to the number of arcs in the network, again with worst case complexity of O(|A|) (Wood, 1998).

As mentioned previously, a topological sort algorithm can easily be combined with a longest path algorithm to form a more efficient joint algorithm. This joint algorithm is the preferred network solution method when a network has not previously been topologically ordered. A representation of the joint topological sort and longest path algorithm is shown in Figure 3 (Ahuja et al, 1993; Wood, 1998).

```
algorithm LongestPath with TopologicalSort;
data G(A,N), the graph G composed of the set of arcs A and the set of nodes N
begin
    for ∀i ∈ N do
    begin
        indegree(i) ← 0;
        longestpath(i) ← −∞;
    end;
    for ∀(i,j) ∈ A do indegree(j) ← indegree(j) + 1;
    LIST ← Ø;
    next ← 0;
    for ∀i ∈ N do
    begin
        if indegree(i) = 0 then
        begin
            LIST ← LIST ∪ {i};
            longestpath(i) ← 0;
        end;
    end;
    while LIST ≠ Ø do
    begin
        select a node i ∈ LIST,
        LIST ← LIST − {i};
        next ← next + 1;
        order(i) ← next;
        for ∀(i,j) ∈ A(i) do
        begin
            indegree(j) ← indegree(j) − 1;
            longestpath(j) ← max{longestpath(j), longestpath(i) + duration(i,j)}
            if indegree(j) = 0 then LIST ← LIST ∪ {j};
        end;
    end;
    if next < n then G(A,N) contains a directed cycle
    else
    begin
        • G(A,N) is acyclic;
        • LIST contains a topological ordering of nodes;
        • longestpath(i) represents the longest path from the start node to node i;
    end;
end;
```

Figure 3. Longest Path Algorithm

In order to represent projects, or military missions as a network, the component tasks, events, and dependencies must be represented in the network graph as activities and events. Activities represent a part of the mission or plan such as a specific task that requires dedication of resources and a period of time to complete. Events, on the other hand, represent a particular instant in time at which a specific part of the plan

(an activity) will start or finish. (Morris, 1967)

There are two typical conventions for representing the graph nodes and arcs as events and activities: Activity on Node (AON) or Activity on Arrow (AOA). Each representation method has both advantages and disadvantages.

In the AON convention, nodes represent activities as well as the start and finish events of an activity while arrows are used only as a means to represent interdependence between activities (Lockyer and Gordon, 1991). The AON convention is powerful in its simplicity as all relevant information is contained within the nodes of the graph without reliance on information in both the arcs and the nodes which requires more detailed computations and tracking.

In the AOA convention, arcs represent activities while nodes represent events (Lockyer and Gordon, 1991). The need to maintain critical information on both arcs and nodes in the AOA convention, in contrast to AON, makes AOA networks more complex and their solutions more involved. In addition, since the dependencies of activities is indicated by sequence of events, there may be times when artificial, or "dummy," activities need to be inserted in a graph to establish dependencies between events that could not otherwise be represented in the AOA convention. This need for dummy activities is a major drawback in the AOA convention, and has led to greater adoption of the AON convention.

The system put forward in this research uses the AON convention due to its simplicity in construction and representation and ease of solving. This is especially useful due to its intended use by military personnel who are not operations research analysts. AON is also used in many commercially available project management systems.

A military operation is represented in this system as a network contained within a graph object. The graph is composed of numerous nodes and arcs that are entered by planners to represent the different elements of the operation from inception to completion along with the dependencies that define the relationships between the elements.

SOMPASS contains tools that convert the nodes and arcs of a graph into representations of the nodes and arcs that are understood by and can be displayed on a map display component to allow a view of the network and simplify manipulation and modification of its elements.

After receiving a mission, commanders and their staffs have many responsibilities during the planning process, regardless of whether it will be the deliberate or compressed planning sequence. Some of these responsibilities include breaking down a mission into its specified, implied, and essential tasks; identifying critical decision points, developing a concept of the operation and COAs; wargaming the COAs; and producing the OPORD.

In this system, an operation is broken down into its component elements: the tasks that participating units must accomplish, and the events that identify the phases and states of progress. These tasks and events come from the planning process and must then be input into the system. Each task that must be accomplished by a unit in support of the mission is translated to an activity of the model that is represented as a node on the graph since this system uses an AON representation. These nodes must also contain information that represents the beginning and end events of each activity.

Each node on the graph has many important pieces of information that must be associated with it in order to be useful in identifying it as well as solving for the critical path of the operation and presenting

the results in a useful manner. Some examples of mission activity properties are the name of the responsible unit, an associated location, time required to complete the task, equipment involved, and whether the activity is on the critical path of the operation. As stated before, the nodes of an AON graph must also contain the events that begin and end each activity and this information can also be stored as properties of the nodes.

The arcs in a graph on these AON networks serve only to connect the nodes of events and activities to show dependency for activity completion and may be assigned a property by the system as to whether an arc is on the critical path. Properties may also be added to the graph itself, and several are added by the system to provide information such as the total duration of the mission.

Since the system is dynamic and distributed, changes in the military operation that occur at any time can easily be made to the graph, its nodes and arcs, or the properties associated with them, either automatically, or by any user from any location that is connected to the system. Then all participants and monitors will automatically receive and incorporate these changes in their systems without any additional effort.

FRAMEWORK

In order to develop a useful and powerful mission planning and analysis support system, there must be an underlying architecture that is well designed and structured. This system provides that necessary architecture by building to and incorporating a component-based methodology and providing a simple and user-friendly graphical user interface.

The idea of components as a software design methodology greatly simplifies the design of a system by allowing independent development and expansion of capability without restricting currently available or future functionality. This is a very powerful paradigm that departs from traditional design and overcomes development limitations that hinder many, if not all, of the current military planning and support systems, as well as many similar-in-function commercially available systems.

Components are small software programs or objects that perform specific functions designed to operate easily with other components and larger applications. These components must have well-designed standardized interfaces so that they can interact seamlessly with any other components or programs that also meet the same interface requirements. (Bilyeu, 1998; PC Webopaedia, 1997-1998) The power of components, when implemented properly, is their ability to perform their designed function without any knowledge of or interest in the other components or applications that they interact with. This independence eliminates "hard-wiring" which limits usefulness and functionality, as well as prevents separation from a parent application and reuse elsewhere.

A group of faculty and students at the Naval Postgraduate School, spearheaded by Professors Gordon H. Bradley and Arnold H. Buss, have designed and begun implementation of a logical extension and architectural interpretation of the component-based methodology for software development called the Loosely Coupled Components (LCC) Project. This project focuses on leveraging the power of a highly flexible component architecture to support the rapid development and construction of military planning and analysis tools and systems that will operate seamlessly over extensible networks on heterogeneous computing hardware and software systems. (Bradley et al, 1998)

The architecture provides a framework for the independent design and creation of

military planning and execution components that can be combined rapidly and inexpensively to fulfill wide-ranging operational needs and extended as necessary. The research goal of the project group is to provide answers to the call for advanced military planning and execution systems and capabilities outlined in such documents as Joint Vision 2010 using developing COTS information technology. (Bradley et al, 1998)

A representation of the Loosely Coupled Components Architecture is shown in Figure 4. The process of design and use of components is a continuous cycle conducted as requirements arise. During planning for a mission, or as a crisis develops, military analysts can pull together existing components such as maps, presentation tools, and algorithms, and then develop and incorporate completely new and independent components that might include additional models and tools in support of this new and specific requirement. Then, when the next mission or crisis arrives, due to their flexible design, the components that were created previously can be reused. This architecture offers significant advantages over current and legacy military planning and analysis tools that are static, monolithic, inflexible, and in many cases proprietary. Although there are ongoing efforts to integrate legacy systems, the enhancements these provide are insufficient to provide the interoperability, platform independence, and flexibility required of desired systems, such as MPARE, that can be provided using the Loosely Coupled Component Architecture. (Bilyeu, 1998; Bradley et al, 1998)

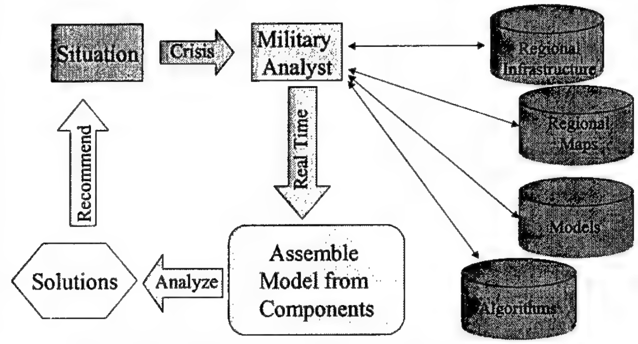

Figure 4. Loosely Coupled Components Architecture (After LCC Demo. 1999)

Several currently available components include tools for conducting discrete-event simulations, map-based planning, and network and graph theory design and analysis (Bilyeu, 1998; Bradley et al, 1998). This project takes advantage of the existing capabilities of these previously developed loosely coupled components, as well as introduces additional functionality, capabilities, and new components to create SOMPASS.

König, a network and graph theory design and analysis component, was developed by MAJ Leroy A. Jackson (1999) of the TRADOC Analysis Center-Monterey (TRAC-Monterey) as an application programmer interface (API) to provide a set of graph and network objects and algorithms to model and solve problems in a loosely coupled component framework. König components offer significant capabilities for real-time dynamic, distributed analysis due to their loosely coupled design. König objects can represent complex network and graph structures with numerous associated attributes that can be dynamically added or modified. Additionally, the König API defines a component framework for implementation of network algorithms that can be used to act on the network objects to conduct detailed analysis. This project expanded on the König framework to develop the longest path network solver algorithm and network graphical display components.

CPT Norbert Schrepf, a German Army officer, developed another set of loosely coupled components collectively called Thistle (1999) in support of his thesis, a *Visual Planning Aid for Movement of Ground Forces in Operations Other Than War* (1999). The Message Center

component of Thistle provides a fundamental distributed communication capability for all loosely coupled components to share information in a simple fashion. Thistle also provides a dynamic map and overlay display tool called Flora that is extremely powerful for planning and monitoring military operations in accordance with accepted doctrinal symbology. An example of a map displayed in Flora can be seen in Figure 5. There are

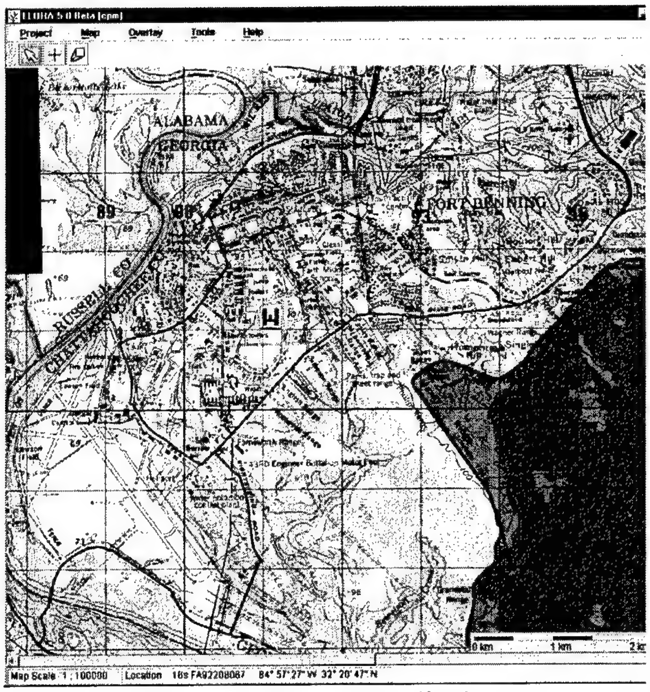

Figure 5. Flora map display

also several other extremely useful tools that complement and leverage the power of other loosely coupled components and provide a common display framework for not only mapping information, but also any type of type of data that can presented in a visual manner. (Schrepf, 1999) As with König, this project attempts to leverage the power of already existing loosely coupled components within Thistle to provide even greater capabilities. Specifically, the Flora map display provides the ability to view mission networks and the Message Center provides the dynamic network notification and update capabilities between all of the elements within the system. Figure 6 highlights the loosely coupled component architecture incorporated in this system.

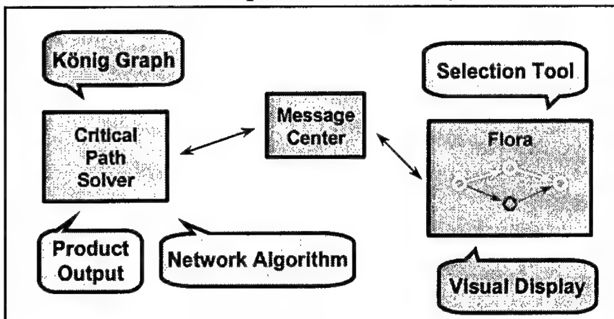

Figure 6. SOMPASS System Architecture

<u>SCENARIO</u>

A notional illustrative scenario of a special operations mission was developed to facilitate an operational demonstration of the system to provide a view of system functionality and capability. The scenario is not based on any known actual previous or planned operations or exercises; it is entirely notional and designed to be unclassified.

This scenario is based on the conduct of a special operations emergency deployment readiness exercise (EDRE) involving a Joint Special Operations Task Force (JSOTF) in an area of operations (AO) in the vicinity of Fort Benning, in Columbus, Georgia. The JSOTF has been formed for the exercise and is headquartered at Hunter Army Airfield (AAF) in Savannah, Georgia. All participating elements are either stationed at or operating from a forward operating base (FOB) at Hunter AAF for the duration of the exercise.

The situation involves a suspected critical enemy facility has been identified by national intelligence assets and must be destroyed. The site is located in an urban environment in the vicinity of several light and motorized enemy units. The enemy units are expected to reinforce the security personnel at the facility to defend the site if it is believed to be in danger.

The mission of the JSOTF is to conduct special reconnaissance (SR) on the suspected facility to verify its purpose and identify defensive capabilities. If the objective is validated as an appropriate target, the JSOTF will conduct a raid to destroy the facility and collect evidence from the site to return for further analysis.

A graphic of the task organization for the JSOTF is shown in Figure 7, while the key actions on the objective are shown in Figure 8.

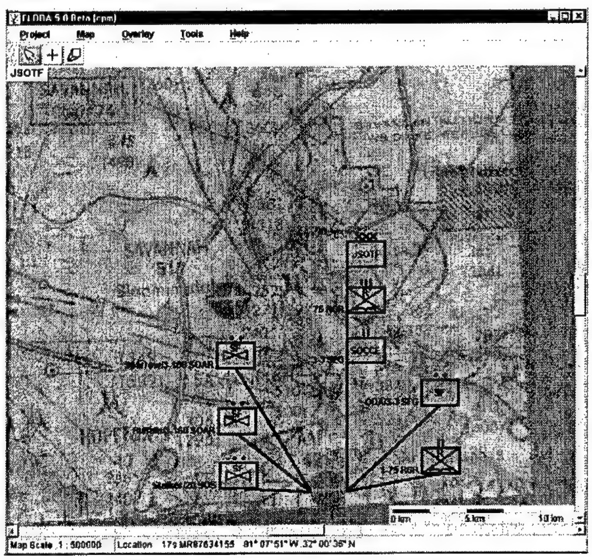

Figure 7. Task Organization

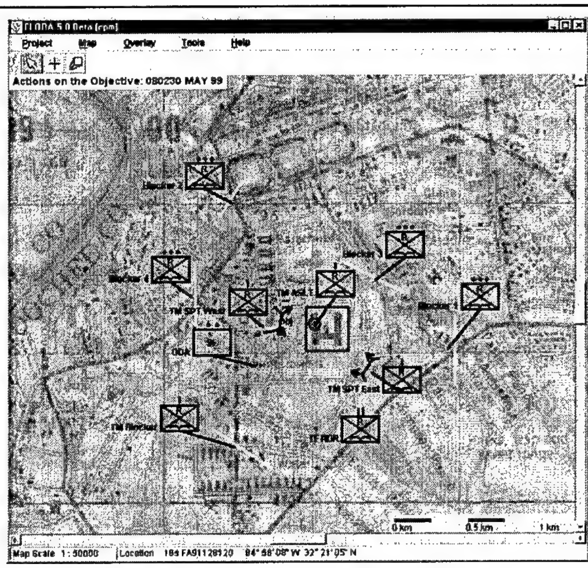

Figure 8. Actions on the Objective

The mission outlined in this illustrative scenario must be broken down into its component tasks and events in order to demonstrate the system capabilities and suitability. The network of the illustrative scenario built with SOMPASS consisted of 23 unit elements and headquarters, 94 nodes representing the mission tasks, and 186 arcs depicting the dependencies between the tasks. A view of the graph of the mission network is shown in Figure 9. Detailed

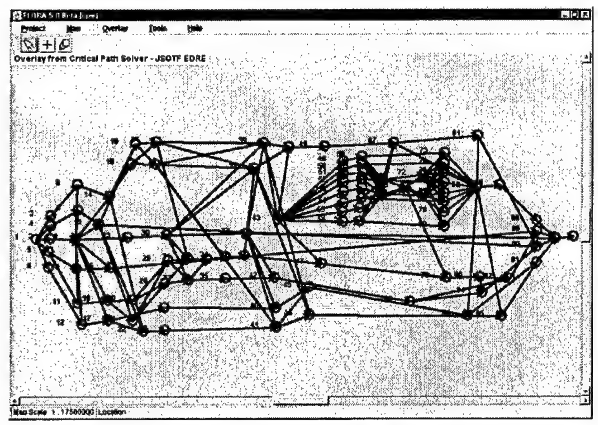

Figure 9. Mission Network Representation

information on the scenario and the task and event list developed for the mission are not included in this paper due to their size, but they can be found in my NPS Master's Thesis of the same title (Hattes, 1999), referenced herein.

SYSTEM OUTPUTS

After successfully solving for the project critical path, the principal features of this system can be exercised — they produce the mission synchronization matrix and unit execution checklists. In addition, information on the mission network is also updated, and the critical path is highlighted in blue for rapid identification.

The synchronization matrix produced by this system presents a time sequenced, unit-hierarchical view of the mission similar to one that would be produced manually during the mission planning sequence. The synchronization matrix produced by this

system is more valuable than those constructed manually because of its interactive and dynamic properties. The left column displays all units involved in the mission, from the controlling headquarters at the top, down through all subordinate elements under their respective parent units. Across the top heading is a listing of critical times in the mission from start to completion. In the body of the matrix are the mission tasks and events associated with their responsible unit and the required times of action or completion. All tasks that are on the critical path of the operation have asterisks ("*") before their names in order to highlight their importance to the viewer. The highlighting helps convey this critical element of information to people who will not see the critical path on the network graph view. A representative view of the synchronization matrix from the illustrative scenario is shown in Figure 10. Unit listings on the left edge can be collapsed to hide their subordinate elements so that a user can easily view the information he is concerned with for a particular unit, or group of units of interest. The table can also be scrolled to view information that is contained in the matrix but not currently visible due to screen size limitations on whatever system it is being viewed.

The execution checklists produced by this system are presented as selectable by a unit tab across the top so that only the checklist for the unit of interest is visible to avoid clutter or confusion. The checklist is shown as a vertical timeline from earliest at the top to latest at the bottom with the time of action or completion shown in the left column, and the required task or event to the right. As with the synchronization matrix, tasks that are on the critical path of the operation are highlighted with an asterisk ("*"). The execution checklist table is also scrollable to allow viewing information not in the present window view. An example view of a unit execution checklist is shown in Figure 11.

Synchronization Matrix for JSOTF EDRE

Unit	29-Apr-99 12:16	29-Apr-99 12:16	29-Apr-99 13:16	30-Apr-99 13:16	30-Apr-99 17:16	02-May-99 17:16	02-May-99 17:16	03-Ma
TaskOrganization								
JSOTF	*Stand Up JSO...	*Stand Up JSO...	Issue Warning ...	*Issue OPORD ...	*Issue OPORD ...	*Await Execute ...	*Await Execute ...	*Await
75 Ranger		*Receive Warni...	*Receive Warni...					
TF Ranger			*Conduct Initial ...	*Conduct Initial ...	*Complete Mis...	*Complete Mis...	*Conduct Rehe...	*Cond
TM Blocker								
Blocker 4								
TM Support West								
Blocker 2								
TM Support East								
Blocker 1								
TM Assault								
Blocker 3								
3-160 SOAR		*Receive Warni...	*Receive Warni...	*Conduct Initial ...	*Complete Mis...	*Complete Mis...		
SOAD Buffalo						*Conduct Rehe...	*Conduct Rehe...	*Cond
SOAD Sparrow						Conduct Rehea...	Conduct Rehea...	Condu
3-3 SFG		*Receive Warni...	*Receive Warni...					
SOCCE								
ODC			*Conduct Initial ...	*Conduct Initial ...	Complete Missi...	Complete Missi...		
ODA			*Conduct Initial ...	*Conduct Initial ...	Complete Missi...	Complete Missi...	Conduct Rehea...	Condu
16 SOW		*Receive Warni...	*Receive Warni...	*Conduct Initial ...	Complete Missi...	Complete Missi...		
20 SOS								
Stalker						Conduct Rehea...	Conduct Rehea...	Condu
4 SOS								
Sentry						Final Mission P...	Final Mission P...	

Figure 10. Synchronization Matrix

ADDITIONAL FUNCTIONALITY

SOMPASS has the potential to offer increased mission planning efficiency and rapid analysis capabilities, both in training and operational environments. As mentioned previously, it could also be integrated into such areas as rehearsal and

execution battle tracking for real-time status monitoring. The highlighting of critical path events on the synchronization matrix and unit execution checklists also offers potential benefit to commanders to indicate where they may want to be located to best lead and direct an operation at its critical junctures.

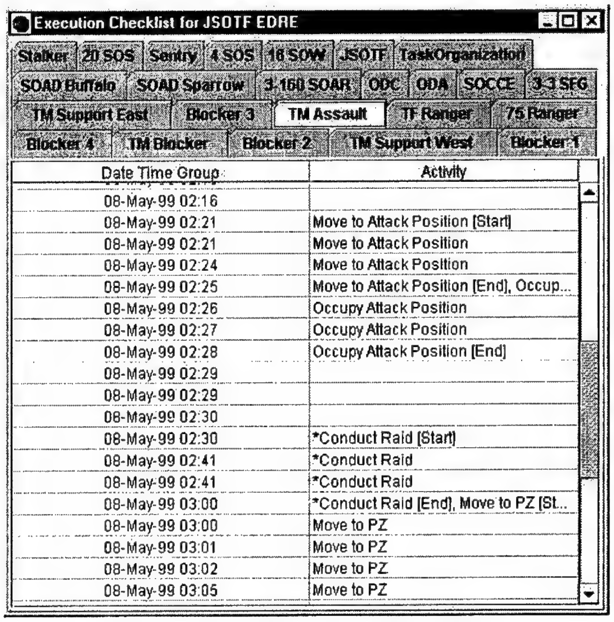

Figure 11. Execution Checklist

In this project and scenario, only the participating units have been presented as the primary key associated with mission tasks, as the battlefield operating system (BOS) for maneuver, but many other areas could be represented just as easily to support operational needs or requirements. Some possibilities include all other BOS components, decision points, and other key activities or time-phased events.

CONCLUSION

This project provides a mission planning and analysis tool, the Special Operations Mission Planning and Analysis Support System (SOMPASS), for Special Operations Forces commanders and staffs to help reduce traditional mission planning preparation time and manual effort requirements, as well as enhance the capabilities for conducting analysis.

SOMPASS uses an operations research approach and incorporates currently available advanced technologies to provide a powerful system to aid in mission planning and analysis. This system helps to reduce mission preparation time and effort by automating some of the requisite tasks involved, thereby giving commanders and staffs more time to focus on other aspects of mission preparation and execution. SOMPASS allows for dynamic property associations and rapid recalculation capabilities so that many possible variations or contingencies may be examined for their effects on mission success before deciding on a final plan. This provides improved COA analysis. Additionally, the dynamic and distributed capabilities of the system allow for multiple users to coordinate their efforts and share information to increase efficiency.

The automated production of synchronization matrices and execution checklists provides an extremely powerful capability to simplify mission synchronization which is a critical element to mission success. Their dynamic nature allows great flexibility for changes with minimal effort, either for analysis purposes or as the situation changes. These products can be distributed and updated over a network to all concerned elements in real-time. This eliminates the confusion generated by current hard-copy products that may be outdated by events and eliminates the need to reassemble staffs to distribute and discuss the latest changes. By highlighting the critical path tasks of an operation, commanders also have a means to identify potential decisive points so they may better determine where to best lead and direct the situation during key phases of an operation.

Due to its dynamic nature, SOMPASS can be used to support all operational phases of a mission, not just the planning phase. Real-time situation updates provided over a network, or entered during an operation will be rapidly incorporated to show any changes or effects on the current plan to allow steps to be taken to address the changing situation. This capability offers great flexibility in planning and response that could not be accomplished with traditional tools or methods.

The design and system architecture of SOMPASS also allows for continued growth and enhancement without the need for total replacement and retraining, thereby meeting the needs of the Special Operations Forces today, and offering potential benefits to all of our Armed Forces in the future.

This report is only a condensed version of all of the research, development, and efforts that went into SOMPASS. The original thesis (Hattes, 1999) goes into significantly more detail for those desiring more information.

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<u>DESCRIPTORS</u>

- Mission Planning
- Analysis
- Synchronization
- Critical Path Method
- CPM
- Special Operations
- MPARE
- Java
- Loosely Coupled Components

LIST OF SYMBOLS, ACRONYMS AND/OR ABBREVIATIONS

AAF	Army Airfield
AAR	After Action Review
AO	Area of Operations
AOA	Activity on Arrow
AON	Activity on Node
API	Application Programmer Interface
BDA	Battle Damage Assessment
BOS	Battlefield Operating Systems
C4I	Command, Control, Communications, Computers, and Intelligence
C4IFTW	C4I For The Warrior
CINC	Commander in Chief
COA	Course(s) of Action
COE	Common Operating Environment
CONOPS	Concept of Operations
COP	Common Operational Picture
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-The-Shelf
CPM	Critical Path Method
CPU	Central Processing Unit
CRD	Capstone Requirements Document
DA	Direct Action
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DISN	Defense Information System Network
DMS	Defense Message System
DoD	Department of Defense
EDRE	Emergency Deployment Readiness Exercise
EET	Earliest Event Time
EFT	Earliest Finishing Time
EST	Earliest Starting Time
FM	Field Manual
FOB	Forward Operational Base
FOL	Forward Operating Location
GCCS	Global Command and Control System
GCSS	Global Combat Support System
GUI	Graphical User Interface
HLA	High Level Architecture
HQ	Headquarters
HLZ	Helicopter Landing Zone, see also LZ
JSOTF	Joint Special Operations Task Force
JTA	Joint Technical Architecture
JVM	Java Virtual Machine
LAN	Local Area Network
LCC	Loosely Coupled Components

LET	Latest Event Time
LFT	Latest Finishing Time
LST	Latest Starting Time
LZ	Landing Zone, see also HLZ
MNS	Mission Needs Statement
MPARE	Mission Planning, Analysis, Rehearsal, and Execution
MVC	Model-View-Controller
NGO	Non-Governmental Organization
ODA	(Special Forces) Operational Detachment Alpha, see also SFOD A
ODC	(Special Forces) Operational Detachment Charlie, see also SFOD C
OOP	Object-Oriented Programming
OOTW	Operations Other Than War
OPORD	Operations Order
PERT	Program Evaluation and Review Technique
PZ	Pickup Zone
RGR	Ranger
RMI	Remote Method Invocation
SBF	Support by Fire
SF	Special Forces
SFG	Special Forces Group
SFOD A	Special Forces Operational Detachment Alpha, see also ODA
SFOD C	Special Forces Operational Detachment Charlie, see also ODC
SIPRNET	Secret Internet Protocol Router Network
SO	Special Operations
SOAD	Special Operations Aviation Detachment
SOAR	Special Operations Aviation Regiment
SOC	Special Operations Command
SOCCE	Special Operations Command and Control Element
SOF	Special Operations Forces
SOMPASS	Special Operations Mission Planning and Analysis Support System
SOP	Standing Operating Procedures
SOS	Special Operations Squadron
SOW	Special Operations Wing
SR	Special Reconnaissance
TA	Target Analysis
TACSOP	Tactical Standing Operating Procedures
TF	Task Force
TM	Team
TRAC	TRADOC Analysis Center
TRADOC	United States Army Training and Doctrine Command
USSOCOM	United States Special Operations Command